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**Estimation of Expected Exchange-Rate Change
Using Forward Call Options**

Roy Stein*

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The views expressed in this paper are those of the author only, and do not necessarily represent those of the Bank of Israel.

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Estimation of Expected Exchange-Rate Change Using Forward Call Options

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Abstract

The public's expectations of exchange-rate changes are an important economic variable in macroeconomic analysis, especially in regard to monetary developments and capital movements of the private sector. Several methods are used to derive expectations; the most accepted of them is based on the spread between domestic and foreign interest rates (the UIP principle). This method assumes implicitly that the risk premium is inconsequential. We argue that this component is in fact substantial and has been growing in recent years. There are several reasons for this, including the liberalization of Israel's forex-market and the introduction of greater flexibility in its exchange-rate regime, both of which have been engendering larger capital movements. The growth of the risk-premium component makes it more important to separate the risk premium from the interest spread in order to determine "net" expectations of exchange rate changes.

This study describes the risk premium and, by means of statistical tests, demonstrates its existence. In our opinion, any estimate of expectations of exchange-rate changes that disregards the risk premium is biased. We show that the magnitude of the risk premium is reflected in the price of the NIS-dollar options, issued by the Bank of Israel, at the forward-at the money strike price. This study concludes that by subtracting the risk-premium component one obtains an unbiased estimate of the public's expectations of exchange-rate change.

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A. Introduction and Review of the Literature

The public's expectations of exchange-rate changes are an important economic variable in macroeconomic analysis, especially in analyzing monetary developments and capital movements in the private sector. It is especially important to monitor expectations in the Israeli economy, a small and open economy in which much activity is related to foreigners. Furthermore, the exposure of the Israeli economy to capital movements has been rising along with progress in financial liberalization.

The forward premium—known in the literature as the spread between the forward rate and the spot rate, and investigated at length in various countries and at different times—has been identified as an estimator of market expectations of exchange-rate change. This assumes that two basic principles are present—the CIP (covered interest parity) principle, in which the forward rate is equal to the interest spread between two countries, and the UIP (uncovered interest parity) principle, in which the interest spread between two countries is equal to the estimate of expectations of exchange-rate changes between these countries.

Insofar as the CIP principle obtains, the UIP principle will point to equality between expectations of exchange-rate change and the forward premium only when the risk premium is equal to zero and expectations are rational.

Most empirical studies support the CIP principle¹ but not the UIP principle,² and they show that the coefficient of the interest spread, as a variable that explains exchange-rate changes between two countries, is not equal to 1 and is actually negative.³ According to Froot and Thaler (1990), the average coefficient in seventy-five empirical studies that have been published is –0.88 and only a few studies obtain a coefficient greater than zero. These results indicate that the expectations estimate is biased, and researchers infer from this that the public is not indifferent to risk and that their expectations are not rational. In the opinion of Fama (1984) and Hodrick and Srivasteva (1986), the existence of this bias proves that the risk premium is not zero; they found

¹ E.g., Frankel and Levich (1977) and Taylor (1989).

² E.g., MacDonald and Taylor (1992), Fama (1984), Froot and Thaler (1990), and Taylor (1995).

³ Engel (1996), Bekaert and Hodric (1993), and McCallum (1994).

that its standard deviation is even greater than the standard deviation of expectations of exchange-rate changes.

The first part of this study affirms the existence of the risk premium by logical inference. The second part calculates the level of the risk premium by means of the prices of special options that the Bank of Israel issues in weekly auctions. The purpose of the study is to estimate the public's expectations of exchange-rate changes by subtracting the estimated risk premium from the forward premium.

The forward premium is biased not only by the risk premium but also by differences in taxation; the study takes this factor into account.

The research period for the estimation of expectations to a three-month forward term is January 1995–September 2001, and to a six-month term it is January 1995–July 2001. Part B of the study presents the risk premium as derived from the options market and measures its share in the forward premium; part C describes the data. Part D uses statistical methods to demonstrate the existence of the risk premium and derives expectations of exchange-rate changes on the assumption that the risk premium is given. Part E shows that the risk premium is volatile and that the extent of its volatility varies over time and in accordance with exchange-rate regimes; evidence of this is provided by means of statistical tests of the premium for various sample periods and under conditions that are typical of different exchange-rate regimes.

B. Methodology

1. Risk Premium

The risk premium is manifested in financial assets in accordance with their level of risk. When there are two fully substitutable investment alternatives, one of which will earn a foreknown real rate of return (ROR) and the other will earn a real ROR that is not foreknown—in terms of the domestic currency—the investor will demand a higher return on the latter asset due to the risk. The added increment is defined as the risk premium. However, the *ex post* rate of return on the

asset of less certain return may, of course, be totally different from that required, due to unforeseen events and changes.

The real returns obtained, in view of known and constant nominal interest rates—in NIS (New Israel Sheqel) terms and in dollar terms—depend on the rates of inflation and exchange-rate change. The real NIS return is affected by the inflation rate; the real dollar return is affected both by the inflation rate and by the change in the NIS–dollar exchange rate.

$$r_d^* = \frac{1 + r_d}{1 + \pi_d} - 1 \qquad r_f^* = \frac{(1 + r_f) \times (1 + E)}{1 + \pi_d} - 1$$

Where r_d is the nominal NIS interest rate that investors demand, π_d is the inflation rate, r_f is the dollar interest rate that investors demand, E is the actual depreciation rate, r_f^* is the realized real dollar return, and r_d^* is the realized real return in NIS.

Any change in the NIS–dollar exchange rate will, as stated, affect the inflation rate in a positive direction.⁴ Therefore, the real NIS return will vary and the real dollar return will vary less (because the numerator is offset in the denominator). This makes the nominal NIS asset riskier to hold. Therefore, those who hold a nominal NIS financial asset, which carries a higher risk, will build a risk premium into the return that they demand. Thus, investors will demand a higher nominal return on an NIS asset than on a dollar asset by the level of the risk premium (RP):

$$\frac{(1 + r_d)}{(1 + E^e) \times (1 + r_f)} - 1 = RP$$

where E^e represents the expected exchange-rate change, r_d the nominal NIS interest rate demanded, and r_f the nominal dollar interest rate demanded.

In approximate computation: $r_d - (r_f + E^e) = RP$.

When we move depreciation expectations to the other side of the equation, we obtain

$$r_d - r_f = E^e + RP.$$

Nessen Marianne (1997) obtained the same equation when he estimated expectations of changes in the dollar exchange rate on the assumption that a risk premium exists.

In contrast to studies that assume that the risk premium is equal to zero, i.e., that $E^e + RP$ reflects expectations of exchange-rate changes, this study assumes that the risk premium is not zero and argues that E^e alone reflects depreciation expectations. Therefore, we subtract an estimate of the risk premium from the interest rate spread.

Below in this part of the study, we demonstrate the size of the risk premium; then in Part D we estimate the expectations of NIS-dollar exchange-rate changes in two alternative ways: (1) the forward premium, an estimation method based on the UIP principle, and (2) the forward premium net of the risk premium, relaxing the assumption that the risk premium is equal to zero.

2. Estimating the Risk Premium

An option⁵ is a financial instrument that gives its owner the right (but not the obligation) to buy or sell a given number of units of the underlying asset at a predetermined price—the strike price. Each option contract has a buyer and a writer (a seller). The buyer has the right to decide whether or not to exercise the option, and if the buyer decides to exercise, the writer of the option must consummate the transaction in accordance with the terms of the option.

There are two basic kinds of options: a call option, an option for the purchase of an underlying asset, and a put option, an option to sell an underlying asset. In a call option, the buyer has the right to acquire the underlying asset and the writer of the option must provide the asset at the strike price if the buyer (the option holder) decides to exercise it. In a put option, the buyer of the option acquires the right to sell the underlying asset and, if the buyer (the option holder) elects to exercise the option, the writer must acquire the underlying asset at the strike price.

An option sold at a strike price that is less than the underlying asset price⁶ is called an in-the-money option and its price reflects, among other things, expectations of a positive cash flow, since the likelihood of exercise is strong. However, a call or put option at a discounted strike price that is equal to the price of the underlying asset is called a “forward at the money” option, (henceforth, forward-at), and its price (or premium) does not reflect expectations of positive cash

⁴ A 70 percent correlation was found between quarterly changes in the dollar exchange rate and those of the Consumer Price Index during the sample period (January 1995–September 2001).

⁵ Ben-Horin, 1996.

⁶ Or a put option at a discounted exercise price that is higher than the price of the underlying asset.

flows, since the strike price is equal to the forward price. Accordingly, not only does this option price contain no built-in expectation of gain; it actually implies an expectation of a loss that is equal to the price of “insurance” against unforeseen changes in the underlying asset. Individuals who are interested in acquiring a forward-at call option in which the underlying asset is the NIS–dollar exchange rate are merely seeking to protect themselves against an unexpectedly large depreciation of the NIS against the dollar—a hedging action. Similarly, individuals who are interested in acquiring a forward-at put option wish to hedge against an unexpectedly vigorous appreciation of the currency.

The Bank of Israel sells these types of forward-at options in weekly auctions, with fixed terms to maturity, whereas the strike prices of options traded on the Tel Aviv Stock Exchange are not necessary equal to the forward rate and their prices are affected by the fact that the term to maturity on each trading day of a given option, varies in accordance with its maturity date. Before each auction, the Bank of Israel sets the strike price on the basis of the spot NIS–dollar exchange rate and the domestic/external interest spread, and determines the maturity date (three and six months ahead).

This study uses the price of call options that the Bank of Israel sells in weekly auctions as a variable that reflects the risk premium, which is defined as the payment that the public is willing to make, and is interested in making, to mitigate the risk arising from fluctuations of the NIS–dollar exchange-rate.

From a derivation related to the Black and Scholes formula for options at a discounted strike price that is equal to the underlying asset price (Hull 1992), one may see that the option price is a function of the NIS–dollar exchange rate, the dollar interest rate, the implicit standard deviation, and the term to maturity. Therefore the price of this option divided by NIS-dollar exchange rate is a linear function only of the implicit standard deviation of the NIS-dollar exchange rate:

$$C = \frac{S_i}{1+rf} \times \left(N\left(\frac{\sigma \times \sqrt{T}}{2}\right) - N\left(\frac{-\sigma \times \sqrt{T}}{2}\right) \right)$$

Brenner and Subrahmanyam (1998) also developed equations to estimate the value of options at the forward strike price; they, too, concluded that the price of call or put options

relative to the price of the underlying asset is a linear function of the volatility of the asset and of this factor alone:

$$C = P = 0.4 \times S_t \times (\sigma \sqrt{T})$$

Accordingly, these pricing formulae for forward-at options, too, contain no implicit expectation of a gain; the option price relative to the NIS–dollar exchange rate depends on the expected level of risk during the lifetime of the option and represents the price of risk in terms of rate of return.

C. The Data and the Sample Period

The data used in this study are daily yields on three- and six-month Israeli Treasury bills, the LIBOR rate on the dollar, three and six months ahead, and the average price of three- and six-month call options, as determined in the Bank of Israel auctions (see Appendix 1). The estimation periods are January 1995–September 2001 for the three-month model and January 1995–July 2001 for the six-month model—excluding a brief period in late 1998 when the NIS–dollar exchange rate depreciated sharply. The aberrant exchange rate change in October 1998 generated residuals in the estimating equations that are statistical outliers, thereby biasing parameter estimates.

The frequency of observations in the model is dictated by the frequency of issues of three-month call options (twice weekly) and six-month options (once weekly) by the Bank of Israel (see Appendix 1). This frequency in estimating the expectations creates a problem of overlap in the estimation equations, as the interval between observations is shorter than the forecast range. Where this occurs, serial correlation is probable (see Baillie and Osterberg [1991] and Hansen and Hodrick [1980]). If we assume that during a given period (e.g., one month) there were forward exchange-rate forecasts for a lengthy period (e.g., three months) on the basis of information available at the time but that at a later time new information about the foreign-currency market raised the dollar exchange rate, then all the exchange-rate forecasts for the initial month will turn out to have been downward. Conversely, when new information brings the dollar

exchange rate down, all the forecasts for the initial month will turn out to have been upward. By implication, a state of overlap results in positive serial correlation.

This problem may be considered in several ways:

1. One may restructure the frequency of the observations to make the interval between them correspond to the forecast range. This method results in the loss of important information because it severely reduces the number of observations. One may redefine the sample, provided that enough observations remain to obtain statistical significance. Frenkel (1978) and Cornell (1977) used this method.
2. One may not use traditional statistical methods (GLS, regression of differentials, or lagged residuals as an explanatory variable) to resolve the serial correlation. The use of these methods in effect assumes that individuals were aware of some information that actually become available later (the information represented by the lagged residuals) and could not have been used in making the forecast.
3. The use of the Newey and West (1987) estimation procedure solves the serial-correlation problem and does not contravene the rational-expectations model. This method corrects the standard deviations of the explanatory variables in regard to the quantity of correlated lags in the residuals that were obtained by computing the covariance matrix (Hansen and Hodrick, 1980). Its use makes it possible to estimate expectations without violating the premise that they are rational.

This study uses the third method to solve the serial-correlation problem occasioned by the overlap of data.

D. The Model

1. The Estimating Equation

Forward exchange-rate expectations satisfy the following equation:

$$(1) \quad \Delta S_{t,t+k} = e_t^k + \mu_{t,t+k}$$

Where $\Delta S_{t,t+k}$ is the change (in percent) in the NIS–dollar exchange rate during k periods ahead and e_t^k is the expected change in the NIS–dollar exchange rate at time t during k periods ahead. Assuming that individuals' expectations are rational (i.e., that they use all accumulated relevant information), the residuals add up to zero.

$$\sum \mu_{t,t+k} = 0$$

The goal of this study, as of any study that aims to estimate expectations in the capital market, is to find a bias-free estimator. If X is a variable that represents exchange-rate expectations, we would expect to obtain $\alpha = 0$ and $\beta = 1$. In such a situation, one may say that the estimate fully reflects expectations and has no elements other than expectations.

$$(2) \quad e_t^k = \alpha + \beta \times X_t^k$$

Even if α is greater than zero, this would not necessarily indicate that the estimate is biased because this result may be traceable to transaction costs. Therefore, some studies test only β in the null hypothesis.

To test the rational expectation hypothesis about the exchange rate we insert Equation (2) into Equation (1) and obtain:

$$(3) \quad \Delta S_{t,t+k} = \alpha + \beta \times X_t^k + \mu_{t,t+k}$$

This equation allows us to test the expected exchange rate changes against the actual exchange rate changes, during the period. If the null hypothesis (H_0): $\alpha=0$ $\beta=1$ is not refuted at a significant level of 5 percent, one may infer that the estimate is representative of all “pure” expectations of exchange-rate change and that the error in expectations $\mu_{t,t+k}$, is random and independent of other variables.

Below we test two estimates of expectations of change in the NIS–dollar exchange rate: (1) an estimate based only on yield differentials, known in the literature as the forward premium (Equation 4), and (2) one that reflects the expected change in the dollar exchange rate, based on yield differentials less the risk premium (Equation 5):

$$(4) \quad \Delta S_{t,t+k} = \alpha + \beta \times f_t^k + \mu_{t,t+k}$$

$$(5) \quad \Delta S_{t,t+k} = \alpha + \beta' \times fRP_t^k + \mu_{t,t+k}$$

Where:

$\Delta S_{t,t+k}$ – the change (In percent) in the NIS–dollar exchange rate during k periods ahead;

f_t^k –the forward premium, calculated as $f_t^k = [(1+r_d)/(1+r_f)-1]^k$;

fRP_t^k – the forward premium less the risk premium, calculated as

$$fRP_t^k = [(1+r_d)/(1+r_f)-1]^k - RP_t^k ;$$

r_d – the yield on k-month Treasury bills;

r_f – the LIBOR rate on the dollar for k months;

RP_t^k – the price of a forward-at dollar option to term k relative to the known dollar exchange rate on the issue date.

2. Results

Table 1 summarizes the results of the estimating equation and shows the differences between an equation that assumes a zero risk premium (4) and one that assumes the existence of a risk premium (5). The equations were estimated using the Newey-West method with no deletion of observations—a method that helps us cope with serial correlation caused by overlapping data.

Applying Dickey-Fuller (1981) and Phillips-Perron (1988) tests to the estimation equations, we found that the residuals obtained were stationary even though the dependent variable was not stationary—I(1)—and that the independent variable was stationary.

Table 1. Results of Forward Exchange-Rate Estimation (Equations 4–5)

| Regression | Regression with data overlap, using the Newey-West method | | | |
|---------------------|--------------------------------------------------------------|-------------------|-----------------|----------------|
| | 1 | 2 | 3 | 4 |
| α | 0.002 (0.36) | -0.003 (-0.34) | 0.002 (0.56) | 0.004 (0.6) |
| β | 0.31 (0.98) | 0.58 (2.6) | | |
| β' | | | 0.94 (3.12) | 0.74 (3.3) |
| K (months) | 3 | 6 | 3 | 6 |
| No. of observations | 613 | 297 | 613 | 297 |
| R^2 | 0.007 | 0.069 | 0.078 | 0.124 |
| S.E. of Reg | 0.024 | 0.028 | 0.023 | 0.027 |
| P-value (H_0^*) | 0 | 0 | 0.82 | 0.43 |

The values in parentheses are t statistics.

* Null hypothesis (H_0): $\alpha = 0$ and $\beta = 1$.

In the estimation equations that assume a zero risk premium and presume that the public's expectations are reflected in the forward premium (Equations 1 and 2 for 3 and 6 months respectively), the null hypothesis is refuted in both terms to maturity (three and six months). Whereas in the estimation equations those assume a non-zero risk premium and subtract the risk

premium from the interest spread (Equations 3 and 4), the null hypothesis is refuted in neither term.

These estimation results support the belief that a risk premium that affects interest spreads exists. Additionally, the yield differentials of Treasury bills and the LIBOR dollar rate, less the impact of the rate of taxation and the risk premium, reflect the public's expectations of change in the NIS-dollar exchange rate.

F. Behavior of the Risk Premium⁷ under Different Exchange-Rate Regimes

This part of the study uses statistical tests to examine the risk premium under different exchange-rate regimes and shows that the risk premium and its volatility vary from regime to regime. We demonstrate this in two ways:

1. *Comparing premium volatility and level during different periods in which different exchange-rate regimes were applied.* The hypotheses tested are: (A) The more freely the exchange rate is allowed to float, the greater is the possible change and, therefore, the higher is the risk premium, and (B) The more freely the exchange rate is allowed to float, the stronger the effect that any exogenous factor related to the forex market will have on the exchange rate.
2. *Testing the correlation between daily exchange rate volatility and the risk premium.* The hypothesis tested is: a more flexible exchange-rate regime (in terms of trading band), is associated with a stronger relationship between the level of dollar exchange-rate volatility and the risk premium—an indicator that reflects the level of uncertainty in the forex market.

Before we present the results of the statistical tests, we should note that the risk component in the forward rate is 45 percent on average for a six-month term and 60 percent on average for a

⁷ All the statistical tests in this section are for normalized premiums—option prices divided by the dollar exchange rate. This procedure was adopted (a) to eliminate the time trend, which affects non-stationary variables, and (b) to reflect the price per unit of risk in rate-of-return terms.

three-month term. These are high rates, especially in the short term. The risk component as part of the forward rate was computed in the following way (for any time range, K):

$$(\text{PREMIUM}_t/S_t) / (R_{d,t+1}) / (R_{f,t} + 1) - 1$$

Three-Month Risk Premium

We divided the survey period into subperiods, in which we would expect changes in the volatility and level of the premium due to changes in the exchange-rate regime (see Appendix 2). During these periods, Israel used a trading-band type of exchange-rate regime; the differences between the periods reflect the extent of management of the currency basket exchange rate and the width of the band.

Period A: December 1, 1992–December 1995. The basket exchange rate was managed by means of discretionary intervention that strove to maintain stability near the midpoint without formally announcing this policy. There were slight changes within the trading band during this time. The width of the diagonal band was ± 7 percent.

Period B1: January 1996–June 17, 1997. The basket exchange rate was managed by means of rule-based intervention only and there was no intervention within the band. The width of the diagonal band was ± 7 percent.

Period B2: June 18, 1997–September 2001. The diagonal band was expanded upward; a year after the subperiod began, its width came to ± 15 percent (due to differences in the slopes of the limits: 6 percent at the upper limit and 4 percent at the lower). However, since the basket exchange rate was near the lower limit when the change was made, the public may not have considered the change in band width significant.

1. Testing Exchange-Rate Volatility and Level

Below we compare variances and averages of the risk premium between Period A and Period B; the null hypothesis presumes equal variances and averages in both periods.

Table 2: Comparison of Variances and Averages in Periods A and B

| | Period A | Period B | P(H₀) |
|-------------------|-----------------|-----------------|-------------------------|
| Average | 0.009 | 0.013 | 0 |
| Variance | 1.6E-06 | 1.7E-05 | 0 |
| Relative variance | 1.7E-04 | 1.2E-03 | |
| Observations (N) | 316 | 538 | |

As Table 2 shows, the null hypotheses are refuted. The volatility and level of risk vary significantly between the periods. Uncertainty in the forex market is stronger in Period B than in Period A. Therefore, the risk premium and volatility are greater. This result validates the hypothesis that the more freely the exchange rate is allowed to float, the higher and more volatile the risk premium will be.

Next, we compare variances and averages between subperiods B1 and B2; the null hypotheses presume equal variances and averages in both subperiods.

Table 3: Comparison of Variances and Averages in Subperiods B1 and B2

| | Subperiod B1 | Subperiod B2 | P(H₀) |
|-------------------|---------------------|---------------------|-------------------------|
| Average | 0.0125 | 0.0136 | 0 |
| Variance | 6.9E-06 | 1.9E-05 | 0.0003 |
| Relative variance | 5.5E-04 | 1.4E-03 | |
| Observations (N) | 121 | 417 | |

As Table 3 shows, the null hypotheses, that the variances and averages of the risk premium are equal, are refuted. Thus, there is a significant difference between the subperiods in risk-premium volatility and level: in Subperiod B2 volatility is greater and the level is higher.

The main inference that one should draw from these tests is that the public does translate the type of exchange-rate regime into terms of risk. When the basket exchange rate is bounded by a wider band and its management is discontinued, the public understands that the exchange rate is less certain and can fluctuate more vigorously within the band. Therefore, the public is willing to pay more to mitigate the risk.

2. *Testing the Coefficient of Correlation between Exchange-Rate Volatility and the Risk-Premium Level*

Table 4. The Effect of Exchange-Rate Policy on the Risk Premium

| Period | Correlation coefficient | Observations (N) |
|--------|-------------------------|------------------|
| A | 0 | 290 |
| B1 | 0.37 | 146 |
| B2 | 0.77 | 415 |

Examining the correlation between the risk premium and exchange-rate volatility, one may see sizable differences between the periods: in Period A, the correlation between them is zero, because discretionary intervention to keep the exchange rate stable around the midpoint of the band thwarted the influence of dollar exchange-rate volatility on the risk premium.

In Period B1, when the discretionary intervention was discontinued, a correspondence, albeit weak, between the risk premium and exchange rate volatility was observed, probably due to the diminutive distance between the basket exchange rate and the lower limit of the band. Whereas in Period B2, when the trading band was widened and the exchange-rate regime took another step toward a floating situation, the correlation coefficient climbed to 77 percent. These results confirm the hypothesis that the more flexible the exchange-rate regime, the stronger the correspondence between dollar exchange-rate volatility and the risk premium.

Six-Month Risk Premium

The results of the statistical tests for the risk premium to a six-month forward term resemble those shown for three months. However, there were two differences:

- * The average risk premium, throughout the period reviewed, was about 1 percent to a three-month forward term as against 1.8 percent to a six-month forward term—a finding that corresponds to the assumption about the increase in risk premium level as the time range lengthens. However, the six-month risk premium is less sensitive to changes in the exchange-rate regime than the three-month premium; thus, volatility to a six-month term is less sensitive to the effect of temporary factors in the forex market.
- * In Period B2, in which the trading band was widened and the exchange-rate regime took another step towards a floating situation, the coefficient of correlation between exchange-rate volatility and the six-month risk premium was 60 percent—smaller than that obtained for the three-month risk premium. This shows that the longer the forecast range, the less the effect of spot events (level of volatility in the preceding month) on the risk premium required.

F. Conclusion

The main contribution of this study is in calculating an estimate of expectations of NIS–dollar exchange-rate change on the basis of forward premium less risk premium. The calculation was performed with the help of prices of options that have two constant characteristics: (1) a forward-at strike price and (2) fixed terms to maturity (three months and six months).

The results of the estimation equations show that only by subtracting the risk premium from the forward premium can one obtain a reasonable estimate of the public's expectations of changes in the NIS–dollar exchange rate. We also show that the level of the risk premium depends not only on the expected level of risk but also on the exchange-rate regime, the position of the exchange rate within the trading band, and the term to maturity.

The rule we found is that when an exchange-rate regime steps closer to a floating one, the risk premium and its volatility rise. We reached this conclusion by comparing risk premiums in various periods of exchange-rate regimes—a managed exchange rate vs. a non-managed one and a narrow trading band vs. a wide band.

By comparing risk premiums between three-month and six-month terms, we found that two changes occur when the forecast range lengthens:

1. The level of risk premium rises;
2. The premium is less affected by temporary changes—exchange-rate volatility and the distance of the basket exchange rate from the limits of the band.

Appendix 1

Bank of Israel Call Options

In November 1989, the Bank of Israel began to operate in the forward market by auctioning dollar call options. The purpose was to help the NIS forward market to develop. The Bank of Israel first offered three-month NIS–dollar European-type call options “in the money” (i.e., where the strike price equals the dollar exchange rate on the day the option is issued).

In December 1992, the Bank of Israel expanded its selection of options by issuing three-month NIS–dollar call options “at the money forward” (where the strike price equals the forward price of the dollar on the issue date). Six-month call options of this type were first issued in September 1994.

The options are offered in staggered discriminatory auctions with minimum price and fixed supply. Three-month options are issued twice a week, on Tuesdays and Thursdays; six-month options are issued once a week, on Tuesday or Thursday. The issues are made only on days when exchange-rate trading takes place. The estimation equations for three-month and six-month ranges were estimated in accordance with these issued dates.

Appendix 2

Exchange-Rate Regimes and Risk Premium

One of the goals of this study, as stated, is to show that the risk premium is a function of the exchange-rate regime. This appendix presents the main characteristics of exchange-rate regimes, explains how each regime affects the risk premium, and describes the way Israel's exchange-rate regime has changed over the years. By implication, the risk premium cannot remain constant in the long term. In Section E above, we examine this inference by means of statistical tests.

1. *Exchange-Rate Regimes and Their Effects on Risk Premium*

Various exchange-rate regimes are used around the world. Two types of regimes, constant and floating, lie at the extremes of the spectrum. The other regimes are combinations of these two (Ben-Bassat, 1995). The differences among the types of regimes trace to the extent of central-bank intervention in foreign-currency trading, the width of the band within which the exchange rate may float, and, of course, the extent of limitations and/or prohibitions against unrestricted capital movements.

(a) *Constant Exchange-Rate Regime*

In a constant exchange-rate system, the central bank sets the relative price of the domestic currency against foreign currency in an administrative decision that is not necessarily supported by market forces. The central bank intervenes in trading by increasing or reducing the extent of external assets in its possession in accordance with supply and demand. To maintain such a regime, the central bank must maintain enough foreign reserves to meet demand and withstand speculative attacks on foreign currency.

A country can set its exchange rate by indexing it to the exchange rate of a foreign currency or a basket of currencies. When the former option is chosen, the rate against that currency is constant and the rate against other currencies floats in response to changes in the indexed currency. When the index is a basket exchange rate, the basket rate is constant whereas the exchange rates of the currencies in the basket may vary.

(b) Floating Exchange-Rate Regime

In a floating exchange-rate regime, the central bank does not undertake to support any given rate. Since the central bank determines the money supply without committing itself to any exchange rate, the exchange rate floats in response to market forces and the central bank eschews all intervention in the forex market. The volatilities of the foreign currency correspond to changes in supply and demand.

*

Most countries' exchange-rate regimes are arrayed along the spectrum and not at the extremes. Several important characteristics define the regime and its place on the spectrum.

(c) Managed Exchange-Rate Regime

In a managed exchange-rate regime, an attempt is made to influence the value of the domestic currency by carrying out foreign-currency transactions that will prevent undesirable movement of the exchange rate. This intervention has two separate goals:

1. To give the business sector greater certainty about the location of the exchange rate and/or to keep the business sector profitable.
2. To attain an inflation target. When prices are firmly pegged to the exchange rate, changes in the exchange rate lead to changes in inflation.

This type of intervention in setting the exchange rate, in which an explicit trading band is not demarcated, is termed discretionary intervention because the central bank makes no commitment to its perseverance. The exchange rate may be managed in this fashion under a trading-band regime and even under a floating regime.

(d) Trading-Band Regime

In a trading-band regime, the central bank stipulates a band within which the exchange rate may float. The limits of the band are foreknown and the central bank makes a rule-based intervention commitment to them. When the exchange rate is within the band, it may behave as it would under a floating exchange-rate regime, but when it breaches the limits, it behaves as it would in a fixed exchange-rate regime (with intervention by the central bank). Notably, when the public has

strong confidence in the regime, exchange-rate volatility in the middle of the band is different from volatility in a floating-rate regime (Bertola and Caballero, 1992).

The amount of space within the trading band, arrayed around a midpoint, reflects estimations of foreign-currency demand and supply and monetary-policy considerations. The broader the band is, the closer the regime is to the floating type, and vice versa. The band may be horizontal or diagonal. The difference between them is the extent of certainty in the forex market. Certainty is greater if a diagonal band is used, since in the case of a horizontal band the central bank must adjust the width of the band in accordance with changes in cross-currency rates, whereas a diagonal band is structured *ab initio* to reflect expected consumer price index ratios.

(e) Influence of Exchange-Rate Regimes on Risk Premium

The risk premium is the extra return on an asset that is defined (or that the public perceives) as risky—the public’s hedge against unexpected exchange-rate changes. The more uncertain the market is about the exchange rate, the greater the risk premium will be. In a regime that holds the exchange rate constant, certainty in the forex market is high (assuming that the public has confidence in the regime policy) except when speculative expectations develop; therefore, the risk premium is usually negligible and irrelevant as a topic of discussion. In other exchange-rate regimes, the closer they are to the floating type, the more uncertain the market is and the higher the risk premium will be.

The risk premium may also vary within a given regime. In regimes that allow the exchange rate to float partly or fully, the public assumes that the exchange rate has a certain limit or that this limit exists by the very definition of the regime. Therefore, the risk premium varies commensurate with the position of the exchange rate within the band. The closer the rate verges on the upper limit—assuming that the public believes that the central bank will stand behind its policy—the less risk there is of an exceptional depreciation.

2. Exchange-Rate Regimes in Israel

Israel’s exchange-rate regimes have been revised significantly over the years to mitigate waves of buy-and-sell speculation. Large waves of speculation occur due to expectations of exchange-rate

changes that cannot be expressed unless the exchange rate is adjusted administratively. We start our survey of Israel's exchange-rate regimes in 1989 in order to gauge the changes that these regimes underwent during and shortly before the sample period.

(a) 1989–December 1991: Horizontal Trading-Band Regime

In early 1989, Israel replaced its the fixed exchange-rate regime with one using a horizontal band at a width of ± 3 percent around the midpoint, within which the exchange rate might float uninhibitedly. In March 1990, the band was widened to ± 5 percent. During the time that this method was in use, the midpoint was raised on several occasions because of the existence of inflation spreads between Israel and its trading partners. The band moved upward at regular intervals of once every six to eight months and at increments of 6–10 percent each time. Speculative capital movements originating in expectations of adjustments in the positioning of the band (changes in the midpoint) did not decrease when this method was used, especially when it was found that even under this type of regime discrete currency devaluations might occur.

(b) December 1991–2001—Diagonal Exchange-Rate Regime

In December 1991, the exchange-rate regime was adjusted again to place the exchange rate on a defined and foreknown trajectory. This was done (a) to quell speculative capital movements and (b) to reduce uncertainty about the annual rate of exchange-rate change and the real path that the rate would follow. The horizontal trading band was replaced with a diagonal one, of which the midpoint and the width were adjusted in a gradual, constant, and foreknown way. The borders of the band and the midpoint rise each day at a fixed rate so that the annual rate of cumulative increase is also constant and foreknown. The slope of the band is derived from the spread between Israel's inflation target and the expected inflation rates in its trading partners. The width of the band started at ± 5 percent and was widened to ± 7 percent and ± 15 ⁸ percent in 1995 and 1997, respectively. However, the change that thrust the economy toward a floating exchange-rate regime was not the widening of the band but the discontinuation of exchange-rate management in

⁸ In June 1997, the band was widened upward, the slope of the lower limit was reduced to 4 percent, and the slope of the upper limit was held at 6 percent. This brought the width of the band to ± 15 percent after the lapse of one year.

early 1996. This change in policy reduced exchange-rate certainty severely by allowing the rate to float at any point in the band with no central-bank intervention whatsoever.

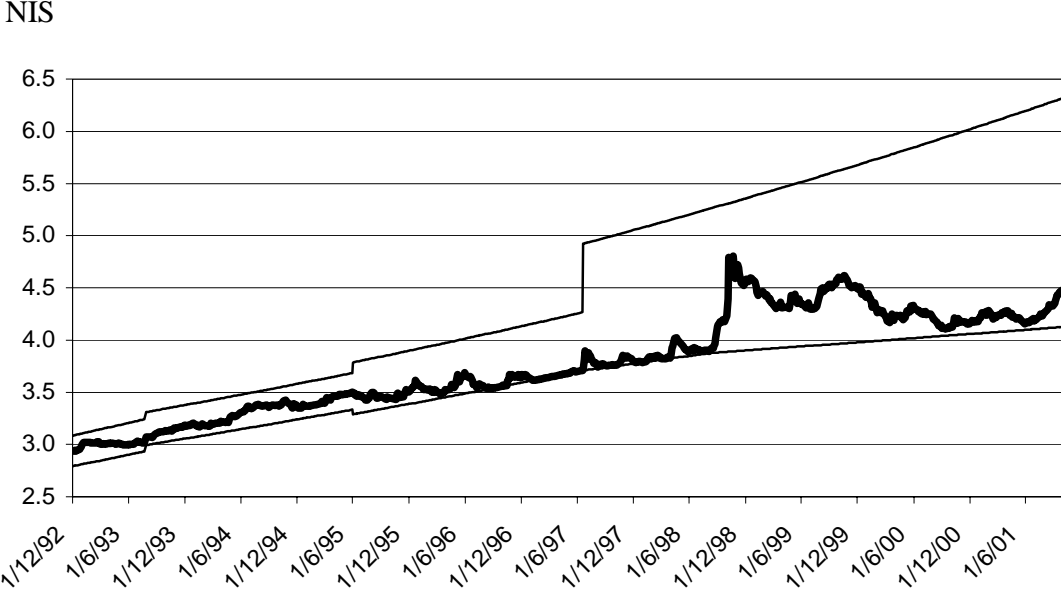
Table A1 and Figure A1 show the changes made in the exchange-rate regime since 1989.

Table A1. Changes in Israel's Exchange-Rate Regime, 1989–2001

| Date | Essence of change |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Jan. 3, 1989 | Introduction of band: midpoint raised by 13 percent (including a 5 percent increase on Dec. 27, 1988). Limits: ± 3 percent |
| June 23, 1989 | Midpoint raised by 6 percent |
| March 1, 1990 | Midpoint raised by 6 percent, band broadened to ± 5 percent |
| Sept. 10, 1990 | Midpoint raised by 10 percent |
| March 11, 1991 | Midpoint raised by 6 percent |
| Dec. 17, 1991 | Introduction of diagonal band: midpoint raised by 3 percent, diagonal slope 9 percent |
| Nov. 9, 1992 | Midpoint raised by 3 percent, slope lowered to 8 percent |
| July 26, 1993 | Midpoint raised by 2 percent, slope lowered to 6 percent |
| May 31, 1995 | Midpoint raised by 0.8 percent, band broadened to ± 7 percent, slope unchanged |
| Feb, 1996 | Discontinuation of discretionary intervention in behavior of the currency basket exchange rate |
| June 18, 1997 | Band widened to ± 15 percent at the lapse of one year, slope of upper limit raised by 6 percent and slope of lower limit by 4 percent |
| Dec. 23, 2001 | Lower limit of band widened by 1 percent and lower end leveled off (0 percent slope) |

Source: Bank of Israel, Foreign-Currency Department, Annual Report, 2001, P. 81.

Figure A1. Currency Basket Exchange Rate and Its Limits



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